REVIEW.

Art. XII.—*Animal Chemistry, or Organic Chemistry in its application to Physiology and Pathology.*—By Justus Liebig, M. D., Professor of Chemistry in the University of Giessen, etc. etc. etc. Edited from the author's manuscript, by William Gregory, M. D., Professor of Medicine and Chemistry in the University and King's College, Aberdeen. With additions, notes and corrections, by Dr. Gregory, and others, by John W. Webster, M. D., Erving Professor of Chemistry in Harvard University. Cambridge: Published by John Owen, 1842—pp. 347.

It must be matter of congratulation in the medical profession, that it has, as a fellow labourer in the investigation of the chemical phenomena of the animal organism, so distinguished a chemist as Dr. Liebig; one who has contributed so largely to the improvement of organic chemistry. Since this branch of chemistry has made such rapid advances, physiologists and practitioners of medicine have desired that the changes taking place in the animal body, might be examined in their chemical relations. This examination is undertaken in Liebig's Report to the British Association. He does not consider the questions he has raised as definitely solved, but that so far as progress has been made, it has been by the only true method, the *quantitative* method. Some of the physiological views will, we think, require modification. It is the duty of the chemist to show that certain tissues are composed of certain elements, that the elements of the blood equal those of bile and urate of ammonia, for instance. It remains for the physiologist to determine by experiment, whether the conclusions drawn by the chemist from such a fact be accurate or erroneous. Any errors in these conclusions, it must be remembered, leave the facts unaffected, and, as facts, worthy of study. We shall endeavour to present as full an analysis of the work as our limits will allow, and especially of those parts which may be more particularly interesting to the physician.

Our author introduces his report by remarks on the vital force, and its influence over all purely chemical action in the animal system. He does not, however, fully explain his views with regard to this agent in this part of the work, but leaves much to the chapter on Motion, in which the subject is resumed, and his deductions examined. Vitality is recognised in two states, that of rest and motion; in the animal ovum and seed of a plant in the state of rest, and in the same ovum and seed, after impregnation in the one, and by the influence of air and moisture on the other, in a state of motion. In this latter condition the vital force manifests itself as a cause of growth in the living animal tissue, and as a cause of resistance to external agencies tending to alter the form and composition of the substance of the tissue, which, simply as a chemical compound, it did not

possess. It destroys the force of attraction exerted between the molecules of food, allowing them to enter into new arrangements identical with those of the living tissues, or differing from them. Again, it appears as a force of attraction, since the compound formed by the new arrangement, when identical with the living tissue combines with and becomes a part of it. The manifestations of the vital force depend upon the form and constitution of the tissue in which it resides; they are also dependent upon temperature and upon a certain amount of food. The manifestations of chemical forces depend upon a certain order in which the elementary particles are united. An analogy is readily perceived in this respect, with the phenomena of vitality; if the form of the body is destroyed, or the arrangement of the elementary particles altered, all vitality immediately ceases; it is inseparable from matter.

There is nothing to prevent us from considering the vital force as a peculiar property, which is possessed by certain material bodies, and becomes sensible when their elementary particles are combined in a certain arrangement or form. Considered in this view the changes which make up the totality of life may be investigated, and the laws which regulate them ascertained, as those which govern the chemical or physical condition of matter. This investigation cannot be conducted as rapidly or as satisfactorily as those just mentioned, so numerous and complicated are the causes acting at each moment of the pursuit; still in some cases we arrive at a degree of certainty, little short of that belonging to the laws of mechanics or chemistry. "Under this form the vital force unites in its manifestations all the peculiarity of chemical forces, and of the not less wonderful cause, which we regard as the ultimate origin of electrical phenomena. When, by the act of manifestation of the energy in a living part, the elements of the food are made to unite in the same form and structure as the living organ possesses, then these elements acquire the same powers. By this combination, the vital force inherent in them is enabled to manifest itself freely, and may be applied in the same way as that of the previously existing tissue."

The manifestations of life in vegetables, are shown in increase of mass and development, and these, as vegetable physiologists and chemists have established, are accompanied by, and depend upon an elimination of oxygen, which is separated from the other component parts of their nourishment. On the other hand, the same phenomena in animal life are accompanied by an absorption of oxygen of the air, and by its combination with the component parts of the animal body. Vegetables appropriate no part of an organised being, until it has first undergone the process of putrefaction and decay, and assumed the form of inorganic matter. Animals require parts of organised beings for their support and development; they are also distinguished from vegetables by the faculty of locomotion, and in general, by the possession of senses. The existence of the faculties, and the use of them, depend upon certain parts never found in vegetables. The phenomena of motion and sensation, depend upon certain kinds of apparatus, which have no other relation to each other than this, that they meet in a common centre. Everything in the animal organism, to which the name of motion can be applied, proceeds from the nervous apparatus. While all the phenomena of motion in vegetables, depend upon physical and mechanical causes. They have no nerves. Assimilation goes on in the same way in animals as in vegetables; the same cause determines

the increase of mass in both. This, which constitutes true vegetative life, manifests itself in vegetables with the aid of external influences; in animals by means of influences which exist within the organism. Although we must admit that digestion, circulation, secretion, are under the influence of the nervous system, yet the force which gives the wonderful properties observed in the germ, the leaf, and the radical fibres of the vegetable, is the same as that enabling the most complex animal organ to perform its function. That increase may take place in the animal organism, contact with the substances to be appropriated is required; this is effected by means of a peculiar circulating fluid, for some of the elements of which each cell and organ have an affinity. Physiology teaches that all parts of the body were originally contained in the blood. Every action of the body involves waste; Liebig even goes so far as to assert, that *every mental affection* is followed by chemical change.

"The most ordinary experience further shows, that at each moment of life, in the animal organism, a continual change of matter, more or less accelerated, is going on; that a part of the structure is transformed into unorganised matter, loses its condition of life, and must be again renewed. Physiology has sufficiently decisive grounds for the opinion, that every motion, every manifestation of force, is the result of a transformation of the structure or its substance; that every conception, every mental affection, is followed by changes in the chemical nature of the secreted fluids; that every thought, every sensation, is accompanied by a change in the composition of the substance of the brain."—P. 8.

This conclusion, to which many would not at first yield assent, is still, as we shall see further on, strictly in accordance with facts, connected with the other tissues of the body, which are indisputable.

To keep up the integrity and functions of parts, thus continually undergoing change, another process must exist, that of supply; the matter appropriated for this purpose, is in all cases a part of an organized being. The consideration of nutrition and reproduction constitutes the second section of Liebig's Report.

If we consider the first condition upon which animal life depends to be assimilation of food, the second is the absorption of oxygen from the air; the phenomena of life are exhibited in the combination constantly going on in the animal body, under the influence of vital force, between the oxygen of the air and food. And it is from the mutual action that all vital activity arises. During the process of nutrition, matter passes from a state of motion to that of rest, (static equilibrium,) to be again set in motion, under the influence of the nervous system. The causes of these conditions of the vital force are chemical forces. Rest is the result of the affinity between the particles of matter; motion arises from the changes taking place in the food, or in the different tissues of the body, the results of decomposition, just as in the closed galvanic circuit, changes taking place in a metal in contact with acid, produce phenomena which we attribute to electricity, so changes undergone by matter constituting the animal organism, produce motion and activity, which we call vitality. This is the point, and no other, from which chemistry should contemplate the phenomena of life. The formation of a crystal is an enigma as well as the formation of an eye, alike difficult to solve.

Taking the view of the animal economy here suggested, we have immediately before us certain striking facts. An adult man receives into his system a certain quantity of food, and at the end of twenty-four hours he

has neither increased nor diminished in weight; during the same time he has also taken into his system a very considerable amount of oxygen. None of this oxygen remains in the system, but is given out again in the form of a compound of carbon or of hydrogen, obtained from the tissues of the body, into combination with which the oxygen has entered. According to Lavoisier and Seguin, the amount of oxygen consumed daily is 32½ oz., and the amount of carbon contained in the food of an adult man for the same time is 13.9 oz.; this amount of carbon escapes from the skin and lungs as carbonic acid gas, and to convert it into the state of gas, 37 oz. of oxygen are required. It is readily seen that, as no part of the oxygen escapes from the body, except as a compound of carbon or of hydrogen, and as these last must be replaced by the food, that the amount of nourishment must be in a direct ratio to the amount of oxygen consumed. Observation confirms what is here stated. The number of respirations is in proportion to the oxygen taken into the system; hence, a labouring man requires more food than one who takes but little exercise; the bird, whose respiration is rapid, requires more food than the serpent, which can fast for three months, and whose hourly consumption of oxygen can hardly be detected. The amount of oxygen contained in the expanded air of summer is less, bulk for bulk, than that of winter; hence the reduction of carbon noticed in the food of those living in warm climates. It is also worthy of notice, that the fruits preferred by the inhabitants of the south, contain but 12 per cent. of carbon, while the blubber and train oil of the arctic regions contain from 66 to 80 per cent. of the same element.

Since the increase of mass in the animal body depends upon the ingredients of the blood, only those substances can be considered as nutritious which are capable of being converted into blood. The composition, then, of the food must be examined and compared with the ingredients of the blood. In considering this fluid we find two chief ingredients, the fibrine, which is identical in all its properties with muscular fibre, when the last is purified from all foreign matters, and the albumen, which is contained in the serum, and is identical with the white of eggs. "Fibrine and albumen contain seven chemical elements, among which are nitrogen, phosphorus, and sulphur; they contain, also, the earth of bones. The serum retains in solution sea salt, and other salts of potash and soda, in which the acids are carbonic, phosphoric, and sulphuric." It is not a little remarkable that chemistry has proved that the two chief ingredients of blood, fibrine and albumen, contain the same organic elements in the same proportion, but arranged in a different order, as the difference in their external properties sufficiently show. Fibrine has also been converted into albumen, or, at least, into a substance having the solubility and coagulability by heat which are the characteristic properties of that substance. These two substances may be converted, by the process of nutrition, into muscular fibre, and this last can be reconverted into blood.

"All parts of the animal body which have a decided shape, which form parts of organs, contain nitrogen; they also contain carbon and the elements of water, although not in any case in the proportion to form water. The chief ingredients of blood contain about 17 per cent of nitrogen, and no part of an organ contains less than this. Experiments prove that the animal body cannot produce either of the elementary bodies above mentioned, carbon or nitrogen, from substances which do not contain it, neither is nitrogen absorbed from the atmosphere in the vital process."

This point is strongly insisted upon by Domas in his leetures; he does not admit that absorption ever takes place; on the other hand, as has been remarked by Despretz, the constant phennmenon is the exhalation of this gas. Indeed, the confusion with regard to the results formerly obtained by different experimenters on the subject, left us in doubt whether nitrogen is influenced by respiration in any way. Sir H. Davy and Cuvier both believed that absorption took place to some extent; Dr. Edwards arrived at the conclusion that both exhalation and absorption occurred, although under different circumstances, dependent principally upon change of temperature. The latest experiments are those of Dulong and Despretz, and they have furnished us with evidence which is irresistible, in at least two hundred experiments made by them personally on the respiration of animals, exhalation was in every instance observed. Water and fat are destitute of nitrogen, and they are unorganized, and only so far take place in the vital process, that their presence is required for the due performance of the vital functions. Nutrition in the carnivora, we can readily see, is more simple than in the herbivora who take elementary particles from substances apparently dissimilar. But a discovery has been made with regard to the compositinn of vegetables, which greatly simplifies the process of nutrition in the class of animals last mentioned. It has been determined that fibrine, albumen, and caseine, in the animal kingdom, are represented by substances bearing the same names in the vegetable kingdom, and which are exactly identical with them in the proportion of their elements; they also very closely resemble them in many of their properties. The clarified juice of turnips, for instance, it is absolutely impossible to distinguish when boiled, and thereby coagulated, from the white of egg diluted with water, and heated to the same point. The three compounds mentioned above, are the true nitrogenized constituents of the food of graminivorous animals; all other nitrogenized substances in plants are rejected by animals, as is the case with the characteristic principles of medicinal plants, whenever they exist in sufficient quantity to have any influence, as regards the increase of mass in the body. We see then that the vegetable principles, which in animals are used to form blood, contain its chief constituents, fibrine and albumen, ready formed, as far as regards their composition. The iron, which is found in the blood, is also found to exist in plants. The animal organism, then, gives to blood only its form, it does not create it from other substances, which do not contain its constituents. It produces new compounds from the constituents, differing from them in composition, but the constituents themselves it cannot produce. In the section on the nutrition of carnivora, Liebig enters more into detail, as it exhibits the process in the two great classes of animals in a manner more readily understond. On examining the substances expelled from the adult serpent, after devouring a rabbit, goat, or bird, we find that the horns, hoofs, hair, feathers, and bones pass unchanged, that they are dry, and all parts capable of solution are absorbed. It is to be observed, also, that when the serpent has regained its original weight, all other parts of the prey have disappeared. The only excrement is that from the urine, which, when dry, affords urate of ammonia; in it, for every equivalent of nitrogen there are two equivalents of carbon. But, in the muscular fibre, blood, membranes, and skin, consumed, the amount of carbon is eight to one of nitrogen, and, if we have regard to the fat and nervous substance, even more. Now, if the urate of ammonia expelled contained all the nitrogen of the animal, at least six equi-

valents of carbon, combined with it, must have escaped through the skin and lungs as oxidized products, as carbonic acid and water. Had the animal food been burned, the same results would have followed, but more slowly. The nitrogen would have appeared with a part of the carbon and hydrogen as carbonate of ammonia, and the remaining carbon and hydrogen would have been given off, as in the animal, in the form of carbonic acid and water, while the ashes and soot would represent the incombustible and imperfectly burned parts of the food. We must not, however, suppose that the oxidized products are given off directly from the food consumed; this would imply that the only object in taking food was their production. The object of food is the restoration of the waste of matter. Certain parts of organs have lost their vitality—have been metamorphosed into amorphous and unorganized combinations, and these are expelled. Exactly as much carbon and nitrogen are supplied by the blood, and, consequently, by the food, as is lost by the waste of matter attendant on the exercise of the functions of the organs. Whenever a portion of matter is thrown off by the tissues, it is immediately carried away by the blood toward the heart.

"These compounds cannot be employed for the reproduction of those tissues from which they are derived. They pass through the absorbent and lymphatic vessels into the veins, where their accumulation would speedily put a stop to the nutritive process, were it not that the accumulation is prevented by two contrivances adapted expressly to this purpose, and which may be compared to filtering machines. The venous blood, before reaching the heart, is made to pass through the liver; the arterial blood, on the other hand, passes through the kidneys; and these organs separate from both all substances incapable of contributing to nutrition. Those new compounds which contain the nitrogen of the transformed organs are collected in the urinary bladder, and being utterly incapable of any further application in the system, are expelled from the body. Those, again, which contain the carbon of the transformed tissues, are collected in the gall-bladder, in the form of a compound of soda, the bile, which is miscible in water in every proportion, and which, passing into the duodenum, mixes with the chyme. All those parts of the bile which, during the digestive process, do not lose their solubility, return during that process into the circulation, in the state of extreme division. The soda of the bile, and those highly carbonized portions which are not precipitated by a weak acid (together making ninety-nine-hundredths of the solid contents of the bile), retain the capacity of resorption by the absorbents of the large and small intestines; nay, this capacity has been directly proved by the administration of enemata containing bile, the whole of the bile disappearing with the injected fluid in the rectum. Thus we know with certainty, that the nitrogenized compounds produced by the metamorphosis of organized tissues, after being separated from the arterial blood by means of the kidneys, are expelled from the body as utterly incapable of further alteration, while the compounds rich in carbon, derived from the same source, return into the system of carnivorous animals."—P. 58.

The oxygen, conveyed by the blood to the different parts of the body, meets with the compounds produced by the transformed tissues and unites with their carbon and hydrogen, forming carbonic acid and water. All that in this way does not suffer oxidation, is sent back into the circulation as bile, and gradually disappears. Hence as all the carbon of the tissues, and all the carbon of the bile, disappears in one of the forms just mentioned, through the skin and lungs, it follows that the elements of the bile serve for respiration and the production of animal heat. "If the excrements of a carnivorous animal be treated with water it will extract from them no bile,

although it is extremely soluble and mixes in every proportion with it. The bile then is all consumed in the animal body." The view here taken of the uses of the bile, and the fact stated that no bile exists in the excrements, are entirely at variance with the generally received opinions of physiologists. It is well known that when the ductus choledochus is tied, constipation takes place, and the fæces change colour. One of the latest authorities in physiology assures us that there can be no question, that by far the largest portion is destined to be entirely thrown off, and it would seem from the character of its proximate elements, as if it were destined to remove from the blood its superfluous hydro-carbon, whether this have been absorbed as such from the aliment, or have been taken up by the blood as effete matter, during the course of the circulation. Bostock taught, that various pathological considerations would induce us to regard the bile as essentially an excrementitious substance, although in conformity with other operations in the animal economy, it is probable that some other purposes are served by it. It is a question worthy of consideration, whether the elements of the bile may not be combined in a different way, as in the case of cholic, choleic, and choloidic acid, the combined elements of which make up the bile, and thus escape detection in the fæces. The origin of the bile and urine are evidently from the transformed tissues, since the secretion goes on while the animal is deprived of food, and during the winter sleep of those that hybernate. The urine is also evidently increased by exercise which increases the amount of metamorphosed tissue. In the adult carnivora, since it neither gains nor loses weight from day to day, the nourishment and waste of tissues must be equal. In the young of the same class of animals the weight increases; here, we must suppose the process of assimilation is more active than that of transformation. But the consumption of oxygen is greater, bulk for bulk, than in the adult; the motion of the blood also is more rapid, the substance of its organized parts would, therefore, undergo a more rapid consumption and yield to the action of oxygen, if the carbon and hydrogen were not supplied from another source; this source is found in the milk of the mother. The carbon and hydrogen of the butter, and the carbon of the sugar of milk, are consumed in the respiratory process and given out as carbonic acid and water. It is in consequence of these substances, which have no other office than to prevent the action of oxygen, that growth takes place. It is not, however, from their assimilation that increase ensues, for they contain no nitrogen. The substance which is assimilated and becomes a part of the living tissue, is the caseine of the milk, which analysis shows to be identical with fibrine and albumen. To convert it into blood no foreign substance is required. It is also found to contain a much larger proportion of the earth of bones, than that fluid, in a soluble form in which it can reach every part of the growing body.

The graminivora, during their whole life, depend on substances having a composition identical with, or closely resembling sugar of milk. Everything consumed by them as aliment contains starch, sugar, or gum. The first named substance, starch, is the most widely extended, and, as is well known, may be converted into a kind of sugar, known as grape sugar, either by the process of germination, or by strong acids. This change depends, according to analysis, upon the addition of the elements of water; no carbon is separated, and nothing added, but the oxygen and hydrogen. A close connection thus exists between sugar and starch. Another kind of

sugar, sugar of milk, also resembles starch; it is incapable of the vinous fermentation by itself, but, when heated with a substance in a state of putrefaction, will resolve into carbonic acid and alcohol. Gum, the third substance mentioned, has the same composition as cane sugar, but, unlike sugar of milk, does not resolve itself into carbonic acid and alcohol when placed in similar circumstances. For the same number of equivalents of carbon 12, the number of equivalents of water will be in starch 10, cane sugar and gum 11, sugar of milk 12, grape sugar 14.

The part performed by the substances above mentioned, in the vital process of the graminivora, is very similar to that performed by the butter and sugar of milk of the young carnivora. The amount of carbon consumed by the graminivora in the nitrogenized constituents of food is exceedingly small, when compared with the oxygen absorbed by the lungs and skin. The horse, which can be maintained in good condition on 15 lbs. of hay and 4½ lbs. of oats daily, obtains from this amount of food but 4½ oz. of nitrogen, and 14½ oz. of carbon; of this last only about 8 oz. can be consumed in respiration, since, with the nitrogen expelled in the urine, there are 3 oz. combined as urea, and 3½ oz. of hippuric acid. But, according to the observations of Boussingault, a horse expires about 79 oz. of carbon daily. He receives then about one-fifth of what is required for the respiratory process. The remaining four-fifths must be supplied in other substances, or his organism will be destroyed by the action of the oxygen; this supply is found in the sugar, gum, and starch. If we apply the principle here set forth, to the nourishment of man, we shall see that a very close connection exists between agriculture and the multiplication of the human species. A nation of hunters obtain the carbon for respiration from the flesh and blood of animals, which take the place of starch and sugar. But it is proved by chemical analysis, that 13 lbs. of flesh, contain no more carbon than 4 lbs. of starch; hence, an individual with one animal and an equal weight of starch, could maintain life five times the number of days that he could if confined to the same weight of flesh alone.

"Man, when confined to animal food, respires, like the carnivora, at the expense of the matters produced by the metamorphosis of organized tissues; and, just as the lion, tiger, hyena, in the cages of a menagerie, are compelled to accelerate the waste of the organized tissues by incessant motion, in order to furnish the matter necessary for respiration; so, the savage, for the very same object, is forced to make the most laborious exertions, and go through a vast amount of muscular exercise. He is compelled to consume force merely in order to supply matter for respiration."—P. 75.

Cultivation has for its object the production of a maximum of the substances, but suited for assimilation and respiration, in the smallest possible space. When this is accomplished no such waste of motion will be required to obtain the means of respiration as has just been mentioned. Cultivation economizes both force and nutriment.

In comparing the urine of the carnivora with that of the graminivora, it is obvious, that transformation of tissue differs both in form and rapidity, in the two classes of animals. The urine of the carnivora contains phosphates and sulphates; since the fluids contain only traces of these substances, and since all the tissues, except cellular tissues, and membranes, contain phosphoric acid and sulphur, they must be derived from the tissues. In the graminivora, on the other hand, we find alkaline carbonates in abun-

dance, but a very small proportion of alkaline phosphates; whence we infer that the tissues which supply these last are very slowly transformed.

Turning to the assimilative process, we find it exhibiting a very marked difference in the two classes. Carnivorous animals devour their prey only when urged by hunger. They require less food for their support, because their skins have no respiratory pores, and, consequently, they lose less heat than the graminivora. These last eat almost without interruption through the day; their system has the power of converting into organized tissue all the food devoured, beyond what is required to repair the waste of the organism; consequently, they become plump while the flesh of the carnivora is tough and sinewy. It is well known that animals become fat, in which the process of cooling and exhalation are diminished by preventing motion. This occurs in consequence of the absorption of less oxygen, than is required to convert all the carbon of the substances destined for respiration into carbonic acid. The excess of carbon, with the exception of a small portion expelled from the body in the form of hippuric acid, is employed in the production of fat. Hence, it is evident, that the formation of this substance, depends upon the want of due proportion between the food and the oxygen. This proportion can be varied in another way, by providing for the carnivorous animal, for instance, food containing no nitrogen, such as gum, starch, sugar. According to the analysis of Chevreul, human fat, mutton fat, and hog's lard, contain the same relative proportion of carbon and hydrogen, as sugar, gum, and starch; these last can be converted into a substance having exactly the composition of the former by a separation of a portion of their oxygen. Consequently, a very remarkable connection exists between the formation of fat and the respiratory process. The oxygen, set free in the formation of fat, is given out in combination with carbon or hydrogen; these must have generated, in the formation of carbonic acid and water, as much heat as would have been produced by burning the carbon and hydrogen in oxygen gas.

We have seen, in what precedes, that no nitrogenized compound, the composition of which differs from that of fibrine, albumen, and caseine, is capable of supporting life. Animals can form from their blood all parts of their bodies, but all the materials must exist in the blood ready prepared, in every thing but the form. It is in consequence of the difference of composition between fibrine and albumen, and gelatine, that the last cannot be used for a vital process. It is true that a small portion of this substance must exist in the blood, but the demand for it in the system is small, since, in a starving or sick individual, we find that the tendons and those parts which are held together by the gelatinous tissues, still retain their connections, even after the fat disappears, and the muscular tissue takes the form of blood. Experience, however, proves that to the diseased, gelatinous substances are useful as a means of nourishment. It is not improbable that it is dissolved in the stomach, and forms a part of the blood, repairing the waste of tissues similar to itself, and saving the weakened vital powers the labour of forming it from the albumen, fibrine, or caseine. The experience of the Committee on Gelatine, appointed by the French Academy, has decided conclusively, that this substance cannot support life when used as the only food.

Metamorphosis of Tissues.—The second part of the report is upon the metamorphosis of the tissues. The mode in which these parts are formed from the constituents of the blood is pointed out, and the changes they un-

dergo before being eliminated from the body. It is well known to chemists that many compounds exist, both nitrogenized and non-nitrogenized, which, with the same composition in one hundred parts, offer very different external characters. A group of three exists in the case of albumen, fibrine, and caseine. They contain the same proportion of organic elements, although differing in external characters. When either of these substances is dissolved in a solution of potash, and exposed to a high temperature, it is decomposed; if now to this solution acetic acid be added, a gelatinous translucent precipitate is formed, which is precisely the same in character and composition, from whichever of the three it is formed. Further than this, it is found that the precipitate contains the same organic elements, and in exactly the same proportion, as the animal matters from which it is prepared. This substance has been called by Mulder, the discoverer, *proteine*. The chief constituent of the blood and the caseine of milk, may be regarded as compounds of phosphates and other salts, and of sulphur and phosphorus, with a compound of carbon, nitrogen, hydrogen, and oxygen, in which their relative proportion are invariable. Viewed in this light, proteine is the commencement of the tissues, because these are all produced from the blood. It has also been ascertained that vegetable fibrine, caseine, and albumen, treated like the same animal substances, also yield proteine; hence vegetables are the producers of all the proteine, which, when developed by the vital force, and the influence of oxygen and hydrogen, form all the organs and tissues of the animal body. To this we shall readily yield assent, when we consider the development of the chick in the egg. The egg contains no other nitrogenized compound except albumen; the yolk contains the same substance with the addition of a little fat, in which cholesterine and iron may be detected. Now, from these substances, with the addition of oxygen, all the various parts of the young fowl are formed. Hence albumen is the essential substance, and all nitrogenized articles of food, whether derived from the animal or vegetable kingdom, are first converted into this substance before they can become nourishment for animals. All food becomes soluble in the stomach and capable of entering into the blood. In this process of solution the oxygen of the air, and a fluid secreted by the stomach, are the only agents. The oxygen, Liebig supposes, to be introduced into the stomach by means of the *saliva*. This he considers peculiarly adapted for entangling the air in the form of froth, and conveying it with the food to the stomach, where the oxygen combines with the food, and the nitrogen escapes through the skin and lungs. An argument in favour of this supposition may be drawn from the fact, that the herbivora both swallow with the saliva more air, and expire more nitrogen than the carnivora; they also expire more when taking food than when fasting. However this may be, it is certainly quite as plausible a theory as any which has been broached to account for this fluid; it certainly must perform some office in the digestive process, or it would not be secreted in so large a quantity, just at the time when the food is passing to the stomach. The process of digestion is so clearly, and, as it seems to us, so accurately described by our author, that we shall extract what he says upon the subject entire.

"The most decisive experiments of physiologists have shown, that the process of chymification is independent of the vital force; that it takes place in virtue of a purely chemical actioo, exactly similar to those processes of decomposition or transformation which are known as putrefaction, fermeotatioo, or

decay, (eremacausis). When expressed in the simplest form, fermentation or putrefaction may be described as a process of transformation,—that is a new arrangement of the elementary particles, or atoms, of a compound, yielding two or more new groups or compounds, and caused by contact with other substances, the elementary particles of which are themselves in a state of transformation or decomposition. It is a communication, or an imparting of a state of motion, which the atoms of a body in a state of motion are capable of producing in other bodies, whose elementary particles are held together only by a feeble attraction. Thus the clear gastric juice contains a substance in a state of transformation, by the contact of which with those constituents of the food, which, by themselves, are insoluble in water, the latter acquire, in virtue of a new grouping of their atoms, the property of dissolving in that fluid. During digestion, the gastric juice, when separated, is found to contain a free mineral acid, the presence of which checks all further change. That the food is rendered soluble quite independently of the vitality of the digestive organs, has been proved by a number of the most beautiful experiments. Food enclosed in perforated metallic tubes, so that it could not come into contact with the stomach, was found to disappear as rapidly, and to be as perfectly digested as if the covering had been absent; and fresh gastric juice out of the body, when boiled white of egg, or muscular fibre, were kept in contact with it for a time at the temperature of the body, caused these substances to lose the solid form and to dissolve in the liquid. It can hardly be doubted that the substance, which is present in the gastric juice in a state of change, is a product of the transformation of the stomach itself. No substances possess, in so high a degree as those arising from the progressive decomposition of the tissues containing gelatine or chondrine, the property of exciting a change in the arrangement of the elements of other compounds. When the lining membrane of the stomach of any animal, as, for example, that of the calf, is cleaned by continued washing with water, it produces no effect whatever, if brought into contact with a solution of sugar, with milk, or other substances. But if the same membrane be exposed for some time to the air, or dried, and then placed in contact with such substances, the sugar is changed, according to the state of decomposition of the animal matter, either into lactic acid, into mannite and mucilage, or into alcohol or carbonic acid; while milk is instantly coagulated. An ordinary animal bladder retains, when dry, all its properties unchanged; but when exposed to air and moisture, it undergoes a change not indicated by any obvious external signs. If, in this state, it be placed in a solution of sugar of milk, that substance is quickly changed into lactic acid. The fresh lining membrane of the stomach of a calf, digested with muriatic acid, gives to this fluid no power of dissolving boiled flesh or coagulated white of egg. But if previously allowed to dry, or if left for a time in water, it then yields to water acidulated with muriatic acid, a substance in minute quantity, the decomposition of which is already commenced, and is completed in the solution. If coagulated albumen be placed in this solution, the state of decomposition is communicated to it, first at the edges, which become translucent, pass into a mucilage, and finally dissolve. The same change gradually affects the whole mass, and at last it is entirely dissolved, with the exception of fatty particles, which render the solution turbid. Oxygen is conveyed to every part of the body by the arterial blood; moisture is everywhere present; and thus we have united the chief conditions of all transformations in the animal body."

To some, perhaps, the idea suggested by the term eremacausis will be that of fermentation, similar to what takes place in sugar and animal substances, and which is accompanied by the disengagement of gas. But it must be borne in mind that there are many cases of complete changes in the arrangement of the elements of a compound without the disengagement of any gas whatever. It is this last which bears a resemblance to the process of digestion. The fact that all substances which can arrest the phe-

nomena of fermentation and putrefaction in liquids, also arrest digestion when taken into the stomach, adds not a little to the probability that the two processes are similar. The free acid found in the gastric juice is the muriatic. This acid is derived from common salt, which is an important agent in converting fibrine and caseine into blood; its power of dissolving bone earth is remarkable, its action upon acetic acid is equal to that of lactic acid, consequently, the necessity formerly supposed for this last acid does not exist. Iron also has been found in the gastric juice, which undoubtedly plays an important part in the formation of the blood.

The formula for Proteine, which is the result of the best analyses expressed in equivalents, is C. 48, H. 36, N. 6, O. 14; and this is also the relative proportion of the organic elements of the blood. Albumen and fibrine contain besides these elements sulphur and phosphorus, the former more sulphur than the latter; and caseine contains besides proteine, sulphur. The state in which sulphur and phosphorus exist in these substances is not well known, nor the exact quantity. From albumen and fibrine all the tissues of the body are formed in one of two ways, either, by the addition, or subtraction, of certain elements. As an example of the changes which may take place in the formation of the various organic substances, the following table is given derived from the researches of Mulder and Scherer. In this table the phosphorus and sulphur are not given in equivalents, but in their relative proportions in the different tissues.

Composition of Organic Tissues.

Albumen	C. 48, N. 6, H. 36, O. 14+P+S.
Fibrine	C. 48, N. 6, H. 36, O. 94+P+2 S.
Caseine	C. 48, N. 6, H. 36, O. 14+S.
Gelatinous tissues, tendons .	C. 48, N. 75, H, 41, O. 18.
Chondrine	C. 48, N. 6, H. 40, O. 20.
Hair, horn	C. 48, N. 7, H. 39, O. 17.
Arterial membrane . .	C. 48, N. 6, H. 38, O. 16.

From the table it appears, that when proteine passes into chondrine, the elements of water have been added with oxygen, and, that for the same amount of carbon all the tissues contain more oxygen than the constituents of blood. In the gelatinous membranes, it is to be observed, nitrogen has been added as well as hydrogen, in the proportions to form ammonia. The production of the compounds derived from the blood may be explained in two ways. One is from albumen by the addition of oxygen, of the elements of water, of those of ammonia, accompanied by the separation of sulphur, and phosphorus; the other from proteine by the separation of carbon. The last is the most probable.

It is not a little remarkable that the true formula for the bile, and the key to its metamorphoses, under the influence of acids and alkalies, have been found by means of the view taken by Liebig in the transformation of the tissues. It is perfectly evident, that if the existing organs are derived from the blood and are continually undergoing change under the influence of oxygen in it, that the animal secretions must contai.. the products of this change in the organs. It has been stated that the bile contains the products of transformation containing the most carbon, and the urine those containing the most nitrogen, consequently, the sum of these elements must make up the proportion of these same elements in the blood. If then we subtract from the elements of blood, those of urine and the oxygen and water, which were added during the transformation of the organs, we

shall have the bile; or, if we reverse the process we shall obtain the composition of the urate of ammonia of the urine. The formula for blood and flesh, according to Playfair and Boeckman, is C. 48, N. 6, H. 39, O. 15. The chief constituent of the bile is choleic acid, and if we subtract from its elements the products formed by the action of muriatic acid, ammonia and taurine, we obtain the empirical formula for choloidic acid. If from the formula of choleic acid we subtract the elements of urea and two atoms of water we shall have the formula for cholic acid. So close is the coincidence between these formulæ and actual analysis that there can be no doubt that the true formula of choleic acid has been obtained. If now to choleic acid, which we must recollect represents the constituents of the bile, we add the chemical equivalents of the neutral urate of ammonia, or the urine of serpents, we shall have a formula expressing the composition of the blood with the addition of one equivalent of oxygen and one of water. And, again: if we add to the elements of proteine three equivalents of water we obtain exactly the same formula, with the exception of one equivalent of hydrogen, and this last is the only difference between the formula thus obtained and that given by adding the urate of ammonia to choleic acid. It seems to us that it is thus clearly demonstrated, that the metamorphosis of tissues takes place in the manner pointed out by Liebig, and that choleic acid with urate of ammonia are the results of this metamorphosis. The form of metamorphosis here indicated is that belonging to the lower classes of amphibia and perhaps to worms and insects. The disappearance of uric acid in the higher classes of animals and its replacement by urea depend upon the oxygen absorbed during respiration and the water consumed. In proof of this, it may be mentioned that in the mulberry calculi we find oxalate of lime, and in others urate of ammonia, and this always in persons who take so little exercise that the supply of oxygen has been diminished. Uric and oxalic acid calculi are not found in phthisical patients. The quantity of uric acid and urea depends in no degree upon the food, since a starving man labouring much secretes more urea than another freely nourished but remaining at rest. The urine of the herbivora contains ammonia, urea and hippuric or benzoic acid, but no uric acid; the existence of benzoic or hippuric acid depending upon the quantity of carbon, and consequently upon the amount of motion. Animals that consume much water keep the uric acid, which is sparingly soluble, in a state of solution, whereby the oxygen readily acts upon it and transforms it into carbonic acid and urea. In birds, on the other hand, which drink but seldom, uric acid appears in the urine, notwithstanding the rapidity of respiration and increased supply of oxygen. In the fœtal calf, the transformation of the tissues is effected through the blood of the mother, which affords the proteine. Here it appears that two atoms of proteine with the addition of nothing except two atoms of water, contain the elements of six atoms of allantoine and one atom of chloidic acid, or meconium. But allantoine contains the elements of uric acid and urea; hence we see that the relation between the allantoine of the fœtal calf and proteine, corresponds with that of the constituents of the urine in animals which breathe to their nourishment.

We have spoken above of the origin of bile in the carnivora, but in the herbivora the quantity of the bile is often much too great to be afforded by the tissues themselves. It is ascertained, for example, that of 59 oz. of dry bile secreted by the ox, 2½ oz. is nitrogen. Now, if this nitrogen pro-

ceeded from the metamorphosed tissues, and all their carbon passed into the bile, it would yield an amount of bile corresponding to 7.15 oz. only of carbon. Hence other substances must take part in the formation of bile, and these are the non-nitrogenized parts of the food, starch, sugar, gum, &c. If, as has been stated by Ure, benzoic acid, when administered internally, appears as hippuric acid in the urine, it would seem that the act of transformation of the tissues takes a new form with respect to the resulting products under the influence of matters used as food. It may be remarked that fat forms more rapidly when no salt is present in the food; and that a compound of sodium in some form is necessary for the production of bile. The presence of muriatic acid in the stomach, and soda in the blood, also go to show the importance of common salt in the organic processes. In the carnivorous animal, the soda in the blood, which is only what is necessary to form the blood, is sufficient to form bile with the prodocts of the tissues; but in the herbivora, the quantity of bile is so great that it cannot be obtained otherwise than directly from the food; their organism must have the power of combining all the soda in the food directly in the bile. We cannot, therefore, consider the existence of alkalies in plants accidental, for besides finding them in the bile, their presence is indispensable for the production of the first food of the young animal; without potash, the production of milk would be impossible.

From many facts we are warranted in the conclusion that there are substances which, although they may not become parts of the tissues, are still capable of playing a part in certain vital processes; thero are others which exercise an influence on the nutritive process and on transformation of tissues, although they take no part in the changes which ensue. There are always substances which have a power of communicating the change going on in their own particles to parts of the system capable of undergoing the same change.

Another class of substances exists, consisting of the medicinal and poisonous compounds, the elements of which are capablo of taking a direct or indirect share in the processes of secretion and transformation. Of these there are three kinds: first, those which unite chemically with the tissues or constituents of the body, the vital force being incapable of destroying the resulting compound. Secondly, those which impede or retard those combinations, called fermentation and putrefaction when taking place out of the body, to which certain complex organic molecules are liable. To this class belong essential oils, camphor, empyreumatic substances, and antiseptics. Thirdly, medicinal substances, the elements of which take a direct share in the changes going on in the animal body, although they are not nutritive, nor are they employed by the organism in the production of blood. They all pruduce a marked effect in a comparatively small dose, and many in a larger dose are poisonous. They are probably not decomposed when taken into the stomach, but if insoluble are rendered soluble, that they may enter the circulation, and there alter the quality of the blood. As regards the *modus operandi* of this class of medicinal agents, we must conclude that their elements either take a share in the formation of certain constituents of the body, or in the production of certain secretions. One example of the influence of substances on the secretions has been given in that of starch on the secretion of bile in the herbivora. Our knowledge with regard to the composition of the different secretions, except that last mentioned, is limited; we do know, however, that all of them contain ni-

trogen chemically combined; they all yield ammnniacal products. It is to be noticed, that of the medicinal nr remedial agents, those containing nitrogenized vegetable principles, whose composition differs from that of the nitrogenized elements of nutrition, are distinguished for their pnwerful action on the animal economy. These effects vary from the mildest form of the action of aloes to that of the most terrible poison, strychnia. No remedy devoid of nitrngen possesses a poisonous action in a similar dose. The poisonous action, however, is nnt in proportion to the nitrogen, although it is not independent of it. Snlanine and picrotoxine, which contain least, are powerful poisnns. In the substance last mentinned, the quantity of nitrogen is so small, that it had been overlooked, until, in consequence of the general law above mentioned, it was again examined and detected. Quinia contains mnre nitrogen than morphia. Caffeine and theobromine, the most active principles of coffee and the cacao-bean, the most highly nitrogenized of all vegetable substances, are not poisnnous.

The other nitrogenized vegetable principles, quinine, alkaloids nf opium, &c., appear to act upon the brain and nervnus system chiefly, and not, as those just mentioned, upon the secretions. They accelerate, retard, or alter, in some way, the phennmena of mntinn in animal life. The fact, that these substances are material, tangible and pnnderable; that they disappear in the system; require repetitinn and increase of dose if we wonld repeat and increase the effect; lead us, when viewed chemically, to the suppnsition that their elements take a share in the formation or transformation nf brain and nervous matter.

"However strange the idea may, at first sight, appear, that the alkaloids of opium or of cinchona bark, the elements of codeine, morphia, quinine, &c., may be converted into constituents of brain and nervous matter, into organs of vital energy, from which the organic motions of the body derive their origin; that these substances form a constituent of that matter, by the removal of which the seat of intellectual life, of sensation and consciousness, is annihilated; it is nevertheless, certain, that all these forms of power and activity are most closely dependent, not only on the existence, but also on a certain quality, of the substance of the brain, spinal marrow, and nerves; insomuch that all the manifestations of the life or vital energy of these modifications of nervous matter, which are recognised as the phenomena of motion, sensation, or feeling, assume another form as soon as their composition is altered."—P. 173.

The animal organism has produced the substance nf the brain and nerves from vegetable principles, entering into the formation of proteine, either alone, or, aided by the elements of non-azotized food, or the fat formed from it; consequently, it is not improbable that other vegetable constituents, intermediate between the fat and compounds of proteine, may also be appropriated by the organism. It may give us some hint as to the mode of action of these substances, to know that *cerebric* acid, the peculiar acid of the fat of the brain, approaches more nearly in its composition to cholcic acid than any other. Brain and nervous matter is, certainly, formed, either by the separation nf a highly azotized compound from the elements of the blood, or by the combination of an azotized product of the vital process with a non-azotized compnund, and that, prnbably, a fatty body. There can be no manner of doubt, that the production of nervous matter frnm blond requires a change in the composition and qualities of the constituents of the blood. The compound of proteine may form a first, second, or third, &c., product before it becomes nervous matter, and if a vegetable principle be introdnced into the blood, it may supply the place of any one of these products, if its composition is properly adapted for it.

Another, and important fact is, that the vegetable alkaloids cannot be shown to be related, in composition, to any other constituent of the body, except the brain and nerves, all of which contain nitrogen, and in composition are intermediate between proteine and fat. The brain itself exhibits the character of an acid; those substances which act powerfully upon the nervous centres, morphia, strychnia, and other alkaloids, are arranged in point of activity in the inverse order of the proportions of oxygen they contain, evidently pointing out a striking fact as to the nature of their action. We have seen that ready-formed gelatine may be appropriated by the sick, and the system relieved of the task of preparing it from the blood; in a similar way, it may be supposed, a product of vegetable life may be employed by the organism for the same purpose as that formed by the vital energy.

By late analyses it has been found that the peculiar vegetable principles in coffee and tea, *caffeine* and *theine*, are identical in composition. It is remarkable also, that this substance, with the addition of oxygen and the elements of water, yield *taurine*, the nitrogenized principle of bile. The same is true of the principle of asparagus. If to the elements of *theobromine* the same constituents be added, we have the elements of taurine combined either with urea, carbonic acid and ammonia, or uric acid. It is in virtue of the nitrogen they contain that these substances assist in forming the azotized constituents of the bile. It cannot be denied that such aid may be required where there is a deficiency of motion, and, consequently, a deficiency of that change of tissue which would yield a nitrogenized product for the composition of the bile, and where, also, the non-nitrogenized food is in excess. In such cases, this principle in the food may supply the place of the product derived from the tissues, and consumed in the respiratory process.

Phenomena of Motion in the Animal Organism.—The consideration of motion in animals, constitutes the third part of our author's report. It is introduced by remarks on vitality, and a comparison of its phenomena with other natural phenomena, the laws governing which have been investigated. We have included in our analysis of the first part of this work, the principal facts and observations which introduce the subject of motion; we shall, therefore, omit all that may not be necessary for the explanation of Liebig's views on this subject. To aid us in forming a clear conception of the origin of the mechanical motions in the animal body, recourse may be had to the various wonderful effects of the galvanic battery. When the two kind of plates are brought in contact with an acid and united by a wire, a chemical action begins at the surface of the most oxidizable plate, and the wire acquires certain properties, overcomes resistance, and decomposes compounds, the elements of which have the strongest attraction for each other; yet this wire takes no part in these changes, it is merely the conductor of force. The manifestations of this force follow immediately upon the change in the chemical character of the acid, and the amount of force is in direct proportion to the number of particles of acid undergoing this change. Applying these facts to the investigation of motion in the animal body, we know that the heart and some other organs do not generate moving power in themselves, but receive it from other parts; we know that the nerves are the conductors of force and motion; that where nerves are not found motion does not occur. The excess of force in one organ is carried to other parts which cannot produce it. The motions of the animal

organism are dependent upon a certain change of form and structure in the living part, and the amount of this change stands in a close relation with the amount of force consumed in the motions. Immediately on the manifestation of mechanical force, a portion of the muscle acting, unites with oxygen, loses its vital properties and separates from the living parts. From this relation between change of matter and consumption of force Liebig infers "that the active or available vital force in certain living parts is the cause of the mechanical phenomena in the animal organism." The whole of this part of the report is devoted to the support of this proposition. It cannot be denied, whatever may be the theory, that for any amount of motion an equivalent of chemical force is manifested, that is an equivalent of oxygen enters into the substance of the organ which has lost its vitality. We see, too, that all parts destined for the production of force are traversed in all directions by minute vessels, in which arterial blood continually circulates, carrying a free supply of oxygen. That these are facts we cannot doubt, although we may well doubt whether the cause of the combination of the oxygen with the muscle is, that the nerves have conducted away that which resists the oxygen, the vital force. *Our author supposes that the nerves do this,* in their office of conductors. In accordance with this view, he finds the muscular system interwoven with nerves, while the gelatinous tissues, mucous membranes, tendons, &c. not destined to produce mechanical force, are destitute of them. These last mentioned substances have a composition which would readily allow of their combination with oxygen; one surface of the intestines and the cells of the lungs is constantly exposed to its action, and would undergo change, were it not that other more easily oxidizable substances are present and neutralize it. In this point of view we cannot fail to perceive the importance of the bile to the intestines and pulmonary cells, as well as of the fat, mucus, and secretions generally. The bile, it will be recollected, is afforded by metamorphosed muscular tissue; hence the greater the amount of force expended, the greater the amount of bile to protect these surfaces.

We cannot question that the blood is continually bathing the various parts with their nourishment, and that the living muscular tissue never loses its power of growth; but the force expended, and consequently, the waste of matter is continually varying; it is also obvious that an equilibrium between supply and waste can only occur when the lifeless portion removed is, at the same instant, supplied by a new portion. Growth takes place to about the same extent in equal times. Mechanical effects on the other hand vary greatly in amount during the same time. Now as we can hardly suppose that supply and waste occur at the same instant, there must be in every individual, unless the phenomena of motion are to cease entirely, a condition in which all voluntary motions are completely checked, in which there is no waste. This condition is *sleep.* The involuntary motions continue during sleep, but the amount of force required, and consequently of tissue which loses its life, is confined within narrow limits; but this force, whatever it may be, and that expended in voluntary motions, during the waking state, must be reaccumulated during sleep. In this state, voluntary motion ceasing, the animal approaches to the nature of a plant, in which all its vital energy is employed in growth and nutrition. The living part of a plant acquires, according to Liebig, its whole vital force from the absence of conductors of force. By this means the leaf is enabled to overcome the strongest chemical attractions. The same vital force which in the plant is

an almost unlimited capacity of growth, becomes in the animal body, a source of motion. A wonderful and wise economy has ordained, that what is appropriated as nourishment should have a composition identical with that of muscular tissue. If animals were obliged to decompose carbonic acid, the elements of which are held together with such force, much vital energy would be prevented from assuming the form of moving power. The change of blood into muscular fibre, may take place without loss of force, since it is a mere change of form from a fluid to a solid; all the constituents of the latter floating in the former.

"In what form, or in what manner, vital force produces mechanical effects in the animal body, is altogether unknown, and is as little to be ascertained by experiment, as the connection of chemical action with the pnenomena of motion, which we can produce with the galvanic battery."

We see then that growth stands in a fixed relation to the amount of vital force consumed as a moving power; that the power available for mechanical forces is equal to the amount of vital force in the tissues which may undergo change, and that in a given time only a limited amount of force can be manifested. The amount of azotized food, necessary to restore the balance between waste and supply of matter, is in proportion to the tissues metamorphosed, and the last may be measured by the amount of nitrogen in the urine. Hence we learn that, in whatever way mechanical force has been employed, whether in voluntary or involuntary motions, it must be proportional to the amount of nitrogen in the urine. Health in the adult, must include the idea of equilibrium among all the causes of waste and supply, the absolute amount of which is different at different periods of life. In the child nutrition is active, and the supply exceeds the waste; but as the vital force cannot be employed at the same time in increasing the mass, and in producing mechanical effects, these last must be less than in the adult. In old age, on the other hand, as the mechanical effects have increased, growth ceases, and the whole mass even decreases. The available power is estimated by mechanics to be, in the adult, $\frac{1}{3}$th the weight of his own body, moved during eight hours at the rate of five feet in two seconds. In regaining his original weight, a man regains a sum of force which enables him to repeat the next day the same amount of labour. In seven hours of sleep this amount of force is obtained, consequently we may assume that the mechanical power is in proportion to the number of hours of sleep. The adult man wakes 17 hours and sleeps 7; if the equilibrim is restored in 24 hours, the mechanical effects produced in the waking state, must be equal to the effects produced during 7 hours in the formation of new parts. An old man sleeps $3\frac{1}{2}$ hours, and all other things being equal, he will be able to produce half the mechanical effects of the adult of equal weight. The infant sleeps 20 hours and wakes only 4, hence the force consumed in forming new parts is to the force used in motion as 20 to 4. If we represent the available force of the adult man by 100, and consider this equal to the formative power, the same forces will be represented in the child by 24 and 286, in the old man by 118 and 43; the proportion of increase of mass to the waste, will be in the adult as 100 : 100, in the child as 100 : 9, and in the old man as 100 to 274. With every hour of sleep the sum of available force in the old man approaches the state of equilibrium between waste and supply, which exists in the adult.

The living animal body manifests these effects only at certain tempera-

tures. The abstraction of heat is equivalent to a diminution of vital energy. The cooling process is counteracted by the combination of oxygen with the metamorphosed tissues in the carnivora; in the herbivora a certain amount of heat is generated by those elements of their non-azotized food which can combine with the same gas. The food required by the same individual exposed to different temperatures is unequal, more being consumed in the lower than in the higher temperature, and as the original weight remains the same, it follows that the oxygen absorbed must also be greater in the lower. The amount of tissue metamorphosed being thus augmented, shows that a greater amount of vital force must be rendered available for mechanical purposes. With the external cooling, the respiratory motions become stronger, and more oxygen is conveyed to the blood; but in a given time an unlimited supply of oxygen cannot be introduced into the body, consequently it is only within certain limits that the diminished temperature increases the transformation of tissue. If the cooling go beyond a certain point the temperature of the body falls, the mechanical effects diminish, and a state of sleep ensues, in which all involuntary motions soon cease, and death takes place. In climbing high mountains, where the air is rarified, and less oxygen absorbed in an equal number of respirations, the amount of force available for moving the body diminishes. If any substance be introduced into the system, for which oxygen has a greater affinity than for the animal tissues, these last will be preserved and a limit put to the change of matter in certain parts of the body. Liebig supposes alcohol to supply the place of muscular fibre in combining with oxygen, and remarks that the development of heat in the body after its use, is not accompanied by a corresponding amount of mechanical force. That alcohol is consumed within the body, he infers from the fact that it has never been chemically detected either in the expired air, urine, or perspiration, although the weariness, feebleness of limb, and drowsiness, show that the mechanical force is diminished, still we cannot question that some of these symptoms must be attributed to the influence of alcohol on the nerves of voluntary motion.

In hybernating animals, during their winter sleep, there is no increase of mass; in some, apparent death occurs in consequence of the diminished vital energy; in others the involuntary motions continue, and preserve a temperature above that of the surrounding air. The respirations go on, and the oxygen unites with the fat, covering all those organs which would not otherwise be able to resist its decomposing influence, and which, like the intestines and membranes, are not destined for the change of matter. In this class of animals the active force of the living parts is devoted, during hybernation, to carrying on the involuntary motions: no expenditure taking place in voluntary motion. In animals which have been hunted to death, metamorphosis of all the living parts of its muscular system occurs, and its flesh becomes uneatable. All the available vital force is consumed in voluntary motion, leaving nothing for those that are involuntary, and a fatal syncope follows.

Theory of Respiration.—During the passage of the venous blood through the lungs, the globules change colour and absorb oxygen, and for each volume of oxygen absorbed, an equal volume of carbonic acid is given out. The red globules contain a compound of iron, and no other constituent of the body contains iron. It is to the part which iron plays in the respiratory process, that Liebig directs his attention. The globules

which have lost their oxygen by combining with the various tissues of the body, in their return towards the heart, combine with carbonic acid and produce venous blood; and when they reach the lungs an exchange takes place between this carbonic acid and the oxygen of the atmosphere. The iron in the arterial blood exists in the state of a peroxide, it passes to the capillaries, gives up a portion of its oxygen and becomes a protoxide, it then combines with carbonic acid and returns to the heart as a carbonate; in the lungs it is again exposed to atmospheric air, becomes again a peroxide and returns to the tissues. This hypothesis rests on well known observations, and Liebig proves by calculation that the amount of iron present in the blood is sufficient for transporting twice as much carbonic acid as can be formed by the oxygen absorbed in the lungs. This hypothesis explains the frightful effects of sulphuretted hydrogen and prussic acid, when inspired, by the well known action of these compounds on those of iron, when alkalies are present; and free alkali is never absent in the blood.

All the analytical evidence referred to in the body of the work, is collected in the appendix. It is copious and contains many valuable analyses, some of them undertaken expressly for this work. The analyses of food and of the constituents of the blood are especially full.

In conclusion, we would express our obligation to Professor Webster, for the opportunity he has given us, in his handsome and accurate American edition, of becoming acquainted with so valuable a contribution to chemistry and physiology.